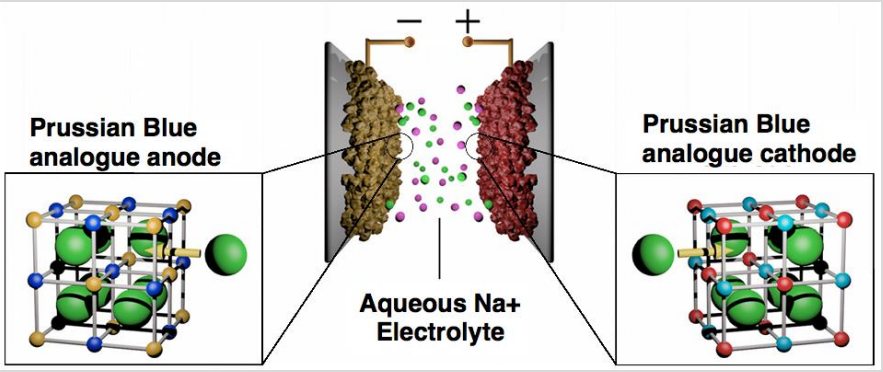
Open Framework Electrode Batteries for Cost-Effective Energy Storage

TEAM:
PI: Colin Wessells, CEO Alveo Energy
colin@alveoenergy.com
Team: Alveo Energy

Technology Overview

- New Na^+ battery chemistry based on Prussian Blue analogue electrodes and aqueous electrolyte.
- Offers 10x cycle life advantage over incumbent cell technologies.
- Projected cell-level lifetime price/energy below$0.02/kWh·cycle.
- Modest cell level energy density of ~50 Wh/L (useful energy).



- Long-cycling open framework electrodes have near-zero strain during cycling.
- Nonflammable, inexpensive Na^+ electrolyte.

Current Status

- Electrode active materials synthesized in house up to 4kg/batch.
- Roll-to-roll electrode production through contract manufacturing partners.
- In house manual cell assembly.
- Full cells show >2,000 cycles at 100% DOD with no change in capacity/energy.
- Full cells deliver up to 80% energy retention at 12C discharge from full charge.
- Largest cells to date = 2 Ah.
- $12M follow on funding secured in March 2016.

Project Statistics

Award Amount	$4.6M arpa-e $1.6M cost share
Award Timeline	March 2013 – March 2016
Next Stage Target	12V/20Ah pack
Collaborations Sought	Electrode and cell manufacturing partners.

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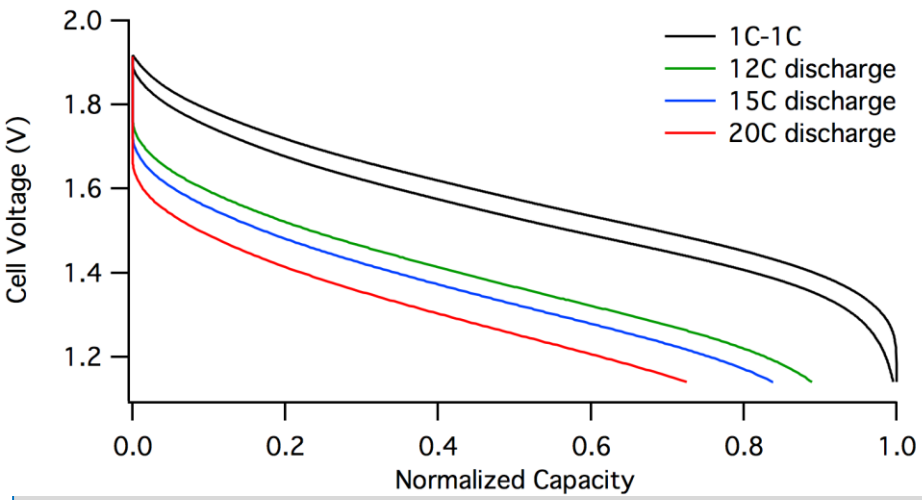
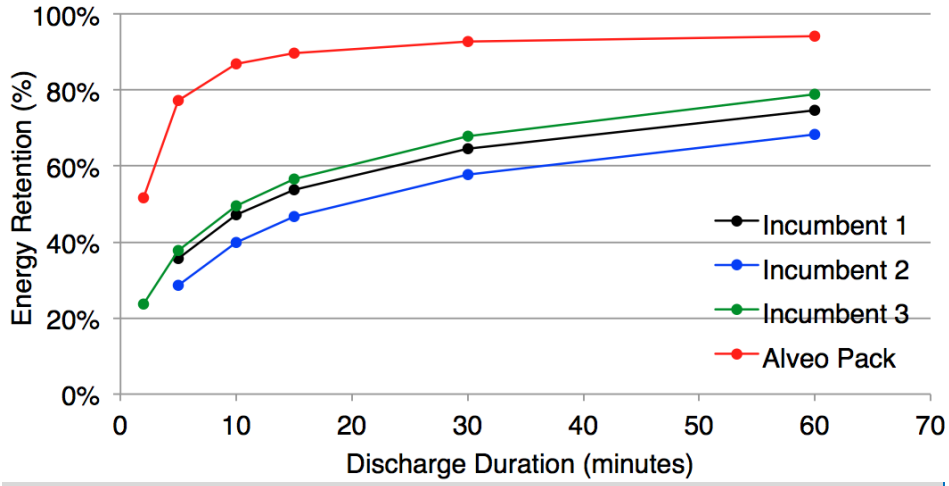
- Successful development of high power, modest energy density cell containing Prussian blue analogue cathode and anode and an aqueous-organic cosolvent electrolyte.
  - Up to 97% DC-DC energy efficiency during 1C-1C cycling (100% DOD).
  - Cells deliver up to 80% of total energy during 5-minute (12C) discharge vs. 30% for industry-leading lead acid packs.

Measured Full Cell Discharge Profiles



Simulated Alveo Pack Energy Retention vs. Lead Acid



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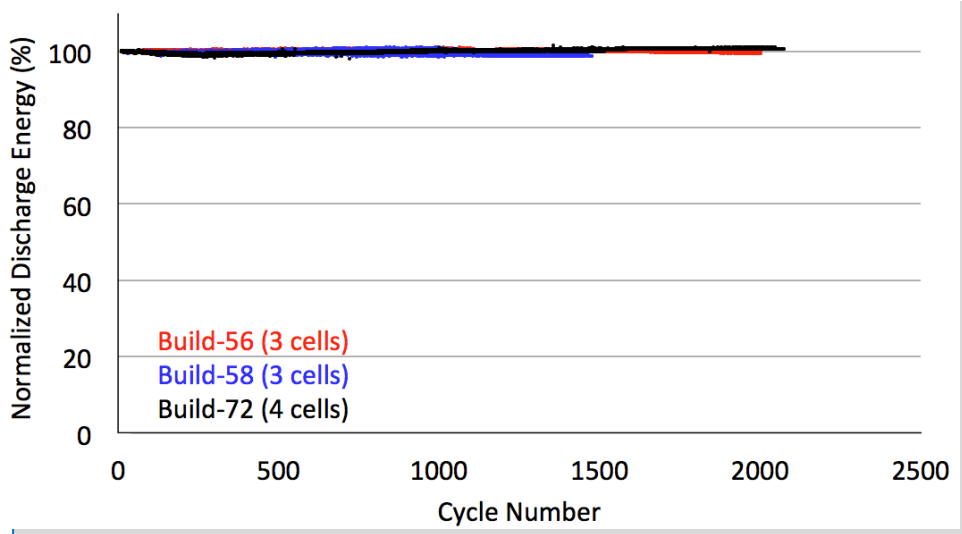
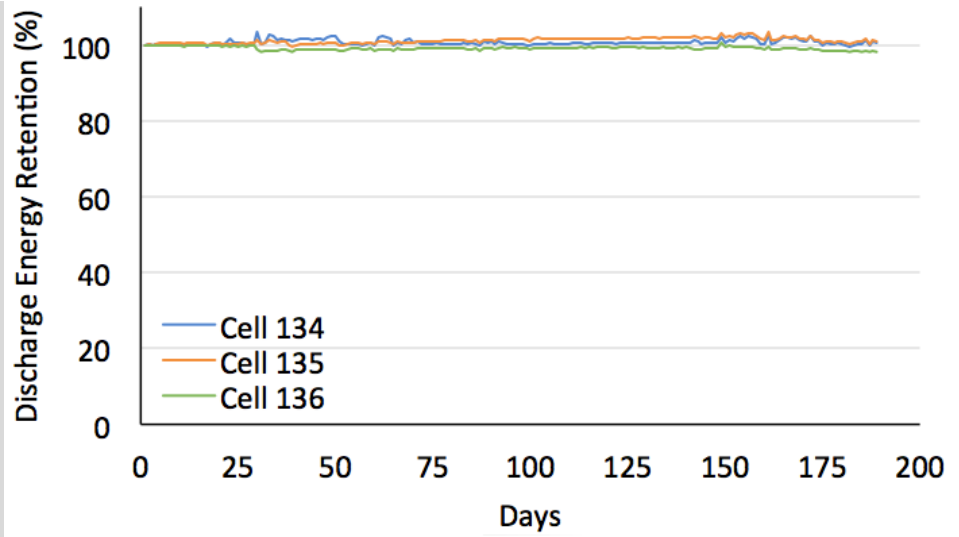
- Cells show zero capacity or energy loss after >6 months of testing under:
  - Constant 1C-1C cycling, 100% capacity utilization, >2,000 cycles.
  - Constant 95% SOC float, daily 100% DOD%, 12C discharge, >180 cycles.

Cell cycle life (100% DOD, 1C cycling, 25° C)



Cell float life (Daily 100% DOD, 12C discharge from 95% SOC)



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- Alveo's value propositions:
  - Cell cost of goods sold (COGS) floor $110-140/kWh with sustained 12C rate capability.
  - Projected 10x longer deep discharge cycle life than Li-ion.
  - ~3x COGS and ~3x calendar life advantage vs. lead acid for short-duration applications.

- Next steps:
  - Duplicate or exceed single-layer pouch cell performance in multi-Ah cells.
  - Design and build BMS-controlled 12V packs.

- Lessons learned:
  - Finish proving out your cell chemistry before attempting scale up. Start by stabilizing the active materials against dissolution/hydrolysis/degradation. Then, minimize the side reactions that imbalance the cell. Only after doing this should one attempt to scale up materials, processes, and cells.
  - Find an initial market for which you have a capex advantage, not a lifetime cost advantage. Investors will be more receptive to value propositions that do not require better lifetime/reliability than other more mature technologies.

- Partnerships we seek:
  - Electrode and cell manufacturing partners.
  - Prospective customers willing to test prototypes and assist in product development.

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